XV. *An Inquiry into the Structure of Seeds, and especially into the true Nature of that Part called by Gærtner the Vitellus. By James Edward Smith, M.D. F.R.S. P.L.S.*

Read November 3, 1807.

Gærtner, so justly celebrated for his anatomical and physiological inquiries into the nature of Seeds in general, and for his particular illustration of One Thousand different kinds, claims the merit of first giving a name and definition to a part called by him the *Vitellus*, which, though not entirely unobserved by preceding philosophers, had received no particular description nor explanation. Before we enter upon the investigation of this organ, it is necessary to consider the structure and functions of the parts of a Seed in general; and this it will be best to do physiologically.

Three agents are necessary to the germination of seeds,—moisture, heat, and air. A seed committed to the ground absorbs, through the vessels of its base, the juices of the soil, or any other moisture that comes in its way; while it receives, throughout its whole substance, a definite portion of heat, some seeds requiring a greater share of the latter, for the purposes of vegetation, than others. Moisture and heat however are not of themselves sufficient to cause the germination of seeds. It has long been known that air is equally necessary; and modern chemists have ascertained oxygen gas to be the particular ingredient of the atmospheric air which is requisite, and which is absorbed by seeds, in

in the moments of incipient germination, from or through the surrounding soil. Thus the bulk of the seed is increased, and its vital principle stimulated. It bursts its immediate integument, or *testa*, and in the first place sends forth the radicle, or young root, into the ground. This part being, as Dr. Darwin well observes, most susceptible of the stimulus of moisture, elongates itself in the direction in which it meets with that stimulus; and descending into the earth, while it fixes the infant plant, assumes its own proper function of imbibing nourishment for the future support of that plant. But before any supplies can be thus obtained, considerable demands are made, even by the root itself; and not only an evolution of parts, but likewise an increase of bulk, takes place in the young vegetable. For this necessary purpose a store is prepared in the *Albumen*, a substance either constituting a separate body by itself, as in grasses, corn, palms, &c., which, from a hard, dry and tasteless mass, changes, by the action of water and oxygen, into a milky or saccharine fluid; or the same substance is lodged in, or united with, the bulk of another part, next to be mentioned, the Cotyledon, or, as they are generally of the plural number, Cotyledons. As the root is the part stimulated by moisture, the Cotyledons appear to be most stimulated by air, and they consequently raise themselves, for the most part, out of the ground in order to receive it, in the form of seminal leaves, well known to perform, for a time, the functions of real leaves, and even, by the action of light, to assume their green colour. The *Albumen* cannot be said to be stimulated, or acted upon as a living body, by the air or gas, which only produces chemical changes in it; and the destination of this substance being soon accomplished, it disappears by absorption. Not so the other parts of the seed, one of which becomes the still descending root, the other

other the nurse, or, if we may say so, the foster brother of the young ascending plant, which last originates from the extremity of the embryo opposite to the root, but always, like that, most intimately connected with the Cotyledons. These indeed, sooner or later, wither away; when the acquisition of real and more ample foliage renders them superfluous, or no longer necessary. But all Cotyledons do not ascend out of the earth, nor assume any of those functions of leaves in which light is concerned. In the Horse Chesnut, the *Cyamus Nelumbo*, the *Tropæolum majus*, and some other plants, they always remain buried, no doubt acted upon by the air or gas alone. Even in plants of the same natural order, *Papilionaceæ*, some, as *Lupinus*, raise their Cotyledons into the air and light, in the form of very conspicuous green seed-leaves; while others, as *Lathyrus*, retain them under ground, concealed in the black skin of the seed, quite out of the reach of every ray of the latter. In these we know a farinaceous *Albumen* is lodged, whether they rise into the light or not; and the closest analogy leads us to conclude that their functions are otherwise similar, which can only be with respect to air. Even Cotyledons however are not indispensably requisite to a seed, though the Albumen appears to be, in some form or other, necessary to all seeds. Not to mention the tribes of vegetables allowed or guessed to be without Cotyledons, and thence, for systematical convenience, denominated acotyledonous; all, who have sufficiently considered the matter, know that in those called monocotyledonous, what is vulgarly taken for the Cotyledon is really an Albumen, a part fundamentally distinct in functions from what is proper to a Cotyledon. Thus even so conspicuous a family of plants as the *Orchideæ*, which the faithful Jussieu confesses were only presumed from analogy to be monocotyledonous, or, as he guardedly expresses it, to have

have "a single-lobed *corculum*," have been shown by Mr. Salisbury, in the 8th volume of our Transactions, the only person I believe who has well examined their germination, to have in fact an Albumen, but no Cotyledon at all. Nor does such ambiguity or uncertainty belong to this family alone. Many plants are presumed to be monocotyledonous, chiefly because they grow in the water; and it is much to be regretted that this fundamental principle of all natural systems should in many cases be so ill-established, and very often so extremely difficult to detect or to determine; which happens in general where its help is most wanted, as I shall presently endeavour to show; but I must first speak of the more immediate object of the present essay.

Gærtner asserts the *Vitellus* of seeds to be "distinct from the "Cotydelons as well as from the Albumen, and, for the most "part, situated between the latter and the Embryo." He considers as its principal diagnostics the 3 following characters: "1st, that it is most closely connected with the Embryo, so as "not to be separable from it without injury to its own substance: "2dly, that notwithstanding this intimate connection, it never "rises out of the integuments of the seed, as the Cotyledons "usually do, in germination, so as to become a seminal leaf, "but, rather like the Albumen, its whole substance is destroyed "by the seedling plant, and converted into its own nourishment: "and 3dly, that if the Albumen be likewise present, the *Vitel-* "*lus* is always situated betwixt that and the Embryo, in such a "manner, however, that it may be separated from the Albumen "with great ease and without injury." For which reasons this able writer considers the organ in question as "allied on the one "hand to the Albumen, on the other to the Cotyledons," but truly distinct in nature from both. He proceeds to observe that

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" it is of all the internal parts of a seed the most singular, and " by far the most unfrequent."

Now, to consider all these points separately, in the 1st place the *Vitellus* is not more closely connected with the Embryo than the greater part of Cotyledons are; according to the figures and descriptions of Gærtner himself, the fidelity of which must be evident to any one in the habit of using his book, and especially to those who will take the trouble of comparing a few of them with the seeds to which they refer, while in the earliest stage of germination, at which time the relative connection of the parts is best ascertained. 2dly, That the *Vitellus* never rises out of the ground, is a circumstance common to it with many Cotyledons, allowed to be such by Gærtner, as in the leguminous plants, and others already mentioned. 3dly, That the *Vitellus* is situated between the Albumen (if the latter be present as a separate organ) and the Embryo, is only a necessary consequence of the more intimate connection between it and the latter than either of them has with any other part, which is also precisely true of the Cotyledons and Embryo, as above mentioned. For these reasons I presume the *Vitellus* to differ in no respect from the subterraneous Cotyledons already described; and that its office is to perform the necessary functions relative to air or oxygen, till the leaves come forth and assume those functions, in greater perfection, with the cooperation of light. This seems more satisfactory than the opinion of Gærtner, that the organ under consideration affords nourishment to the Embryo; because this is abundantly supplied by the copious *Albumen* of a multitude of seeds whose *Vitellus* is very inconsiderable, as grasses; and because it is unphilosophical to recur to two causes, when one is evidently sufficient. In fact, the *Vitellus*, as far as I can observe, only dwindles away when the leaves unfold,

fold, exactly as happens to the subterraneous Cotyledons. The same thing very often takes place as speedily in those which rise out of the ground; the existence of the latter appearing to be prolonged in some instances, merely by their nearer approach to the nature of leaves, as in Umbelliferous and Cruciform plants. The difference of duration is still more evident, and more instructive as to our present purpose, in the Leguminous family, between such Cotyledons as rise above the ground, like Lupines, and those which remain buried, like Vetches, the latter decaying as quickly as any supposed *Vitellus* can do. In Grasses the scale, taken by Gærtner for a *Vitellus*, is mostly so thin and unsubstantial, as not possibly to contain any material portion of nourishment; but its expanded figure is very well calculated, like that of the leaves, for functions analogous to vegetable respiration, and its whole aspect conveys the idea of a primary or subterraneous leaf, quickly rendered superfluous by the production of real leaves, which, as well as the radicle, are probably, in the first stage of their evolution, fed by the abundant juices of the Albumen. It appears that the pretended *Vitellus* is not necessary to all plants furnished with this distinct kind of Albumen. The Palms and *Orchideæ* prove to be destitute of it. On the other hand, I can find no instance of a supposed *Vitellus*, and a real Cotyledon or Cotyledons, in the same plant. What Gærtner terms the Cotyledons of *Rhizophora*, in his *tab.* 45, appears to me to be the *Plumula*, and in his descriptions of some of the *Scitamineæ*, he evidently takes the latter for a Cotyledon.

By understanding the *Vitellus* as a Cotyledon, all ambiguity respecting the component parts of any seed is removed. When the Cotyledons are two or more, the only question is whether the albuminous matter is lodged in their substance, or whether

it forms a separate organ. When the Embryo is accompanied by a simple undivided organ or seed-lobe, we know it to be a Cotyledon by its strict union, or even partial incorporation, with the Embryo, as in *Zamia**; whereas the pure separate Albumen of the true Palms has, as in every other instance, no more connection with the Embryo, according to Gærtner's just remark, than is absolutely necessary; and moreover evinces its true nature by the chemical alteration, and speedy absorption, of its whole substance. The Cotyledon, as I consider it, of *Zamia*, as in numerous parallel instances, shrivels and shrinks indeed considerably, from the absorption of its albuminous contents by the vegetating Embryo, but does not disappear, leaving only a skin behind, like the Albumen of grasses or corn, because that part of its substance which is destined to perform the office, essential to a Cotyledon, concerning air, merely decays when its end is answered. It may further be observed upon this subject, that the albuminous matter of seeds with two or more Cotyledons is commonly of an oily nature, while those with one Cotyledon or none at all, have a more farinaceous, or even stony, Albumen. Still the latter changes to a milky or oily fluid, previous to its absorption. When the vital principle of a seed is extinct, its albuminous oil becomes rancid, and, even in seeds that retain life, is liable to suffer some deterioration by keeping. Hence, as Darwin observes, gardeners preserve Melon and Cucumber seeds, perhaps for years, that the plants they produce may be less luxuriant, in consequence of being starved at their first germination; for any injury to the Cotyledons, even after they

* Mr. R. Brown, who has observed the germination of a large species of *Zamia* in New Holland, assures me that he found no such incorporation of the parts in question as Gærtner has represented in his *t.* 3, and that the structure and evolution of every part bore an exact resemblance to *Cycas* as described by M. Aubert du Petit Thouars.

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begin to rise above ground, is found to cramp the subsequent growth of the plant. The oil of the Cotyledons has been usually supposed a protection to their internal parts, I presume against wet; but this purpose it by no means does or can answer, for all seeds readily absorb moisture whenever they meet with it, and, if likewise exposed to the action of oxygen, they vegetate, in whatever situation they may otherwise happen to be. I suspect moreover that the oily and mucilaginous fluids of seeds in general, before they perform their office in germination, all previously become milky, and often saccharine, from the actions of water and oxygen. It might be worth while to inquire, whether exposure of such seeds as are most prone to turn rancid, to a quantity of oxygen, would tend to preserve them. It is, I believe, found that the admission of some atmospheric air is necessary to the preservation of many seeds. The primary cause of decay therefore in seeds spoiled by keeping may originate, not, as I have supposed, in the extinction of their vital principle, but in the corruption of their albuminous oils; and this is strengthened by the experiments of the French chemists, whose applications may much more readily be supposed to correct and restore the albuminous juices, than to bring the dead to life.

This idea of the albuminous matter, whether oily, mucilaginous or farinaceous, being, when not a distinct and separate body, always lodged in the Cotyledons, throws additional light on the nature of the last-mentioned parts, and in a very beautiful manner confirms their analogy with leaves. The discoveries of Mr. Knight have proved that the nutritious fluid or sap of plants is carried into the leaves, in order to be there acted upon by air, light, heat and moisture. After these agents have produced their effects, the fluids are sent back, through the returning vessels, into the branch or stem, to furnish matter of increase

to the whole vegetable body. The chemical experiments, of Dr. Priestley more especially, confirm this, by teaching us that carbonic-acid-gas is absorbed by leaves in the day-time through their upper surface, and decomposed by them, its carbon being added to the sap, and its oxygen emitted by the under surface. In the dark, leaves are found to absorb oxygen. Let us apply all this to the germination of seeds. The oxygen, known, as I have already said, to be necessary to this process, being conveyed to the seed in its dark subterraneous situation, is absorbed by its Cotyledons, already stored, from the constitution of the parent plant during their formation, with albuminous matter abounding with the carbonic principle. The chemical action of the oxygen on this albuminous substance, renders the latter a more or less saccharine, and, with the addition of the imbibed moisture, a milky fluid, fit to be transmitted, through the returning vessels of the Cotyledons, into the stem of the Embryo, especially as all these important parts have already begun to swell by the absorption of moisture assisted by warmth. Hence we see why light is found hurtful to incipient germination, and why carbonic-acid-gas may be given out by seeds at that period. We perceive also why the outside of seeds is so commonly dark-coloured, or even black, as in *Canna*, *Afzelia*, and others, it being the only part of the vegetable body, as far as I recollect, that is ever positively black, except perhaps the skins of some fruits. It is, moreover, evident that all the indispensable functions of the Cotyledons are best performed under ground, and that when they rise into the air and light, it is not till after their primary destination is fulfilled, and then because, being fundamentally of the nature of leaves, they are also capable, in most instances, of assuming their functions with respect to light. It is highly worthy of notice that, in consequence of the original

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position of the Cotyledons in all seeds, the oxygen gas must always be imbibed by their under side, that very same part which in leaves gives out this kind of gas during the day, and probably absorbs it during the night. It would have evinced a strange contrariety in the constitutions of two organs otherwise so analogous, I mean the leaves and cotyledons, if the *upper* surface of the latter, while in the unexpanded seed, had been presented to receive the oxygen gas. Where there is a separate Albumen, without any perceptible Cotyledons, it is probable that the stalk of the Embryo may answer the necessary purpose; just as the stems of leafless plants must be presumed to perform the usual chemical functions of leaves, though we cannot ascertain in what direction the different airs are imbibed or discharged, there being no decided upper or under surface in such stems, any more than in ensiform leaves. Such, however, are rare exceptions, which if not, as yet, found to throw any new light on the subject, certainly do not overturn any important part of the above hypothesis. That some part, immediately connected with the Embryo, must be stimulated in order to excite the germination of a seed, this phænomenon being dependent on the vital principle, is evident. I conceive that, when present, the Cotyledon or Cotyledons are themselves stimulated by the oxygen gas, or rather by the heat which chemists inform us is produced by the absorption of that gas, so as to set their fluids in motion, and thus to propel the young root and rising *Plumula*. But when the Cotyledons are wanting, the Embryo may very well be conceived capable of sufficient action to imbibe for itself the juices of a distinct Albumen, already become milky and saccharine by the reception of oxygen and moisture, by which merely chemical process, as in barley, so considerable a degree of heat is evolved, as must

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very powerfully excite the vital principle of the budding vegetable. In the few cases where one or more Cotyledons and a distinct Albumen are together present, it does not seem necessary that the gas should act through the former upon the Albumen, the two organs being but little connected, and its operation on the latter being independent of all vital or organic laws; but either the gas itself, or the heat produced, may very well so stimulate the vital principle of the Cotyledons, as to propel their fluids into the Embryo and assist germination. This opinion is the more probable, as those fluids must be supposed more truly of the nature of sap, and more immediately fit for the use of the infant plant, than the liquor of the Albumen. However this may be, the existence of a Cotyledon or Cotyledons, together with a separate Albumen, in seeds, seems to me so unusual, as not to occasion much difficulty, and I would define a Cotyledon to be a vital organ, capable, as such, of being stimulated by oxygen, heat, or both, for the propulsion of its contents; while such an Albumen is merely a repository of nutritious vegetable matter, subject to the laws of chemistry alone, and only passively resigning those contents to the absorbing powers of the Embryo, to which it is attached.

I must now, under the impression of what has just been advanced, return to the arrangement of plants by their Cotyledons.

Plants in general are Dicotyledonous, having a pair of these organs, which commonly rise out of the ground; but if they do not, it appears, from the consideration of the Leguminous tribe, that such a difference could scarcely serve for a generic distinction, much less for that of a Class or Order. It also appears that, if the number of Cotyledons exceeds two, as in *Pinus* and a few other instances, the difference is of little or no use for systematical purposes, and of no physiological importance whatever.

ever. The Cotyledons of *Pinus* all present their backs to receive the oxygen.

Some plants appear to be really furnished with one simple Cotyledon, as *Zamia*, and according to Gærtner's figures and descriptions, the true *Scitamineæ*, as *Amomum* (his *Zingiber*), *Alpinia*, &c.; while *Canna* seems to have no Cotyledon, but only an Albumen. Can this be true? and if so, what is the value of such a distinction in a natural classification? The *Liliaceæ*, *Palmæ*, and now the *Orchideæ*, are acknowledged to be Acotyledonous, having only an Albumen; while the Grasses, so nearly allied to them, have one Cotyledon, for I presume their scale must be admitted as such. Gærtner's phrase of *Embryo monocotyledoneus* applied to these last-mentioned families may occasion a mistake, which would be avoided by the term *Embryo simplex*, or *indivisus*, expressing his idea of the simple figure appropriate to this part in such plants, but which does not prevent its upper extremity being strictly analogous to the *Plumula* of the *Dicotyledones*. It seems to me therefore that this learned writer is mistaken in saying the monocotyledonous plants never have any *Plumula*. They have not indeed that feather-like configuration in the ascending point of their Embryo which gave rise to the name, but the organ so called is, and must be, present. To dispute about the term is as little to the purpose as to contend that the *Orchideæ* have no *pollen*, because it is not of a powdery appearance.

From Mr. Lindsay's account of the germination of Ferns in our 2d Volume, this family must be deemed Monocotyledonous. Their germination seems at first analogous to that of Mosses, as given by Hedwig in his *Theoria*, but the numerous and branched Cotyledons of the latter overset all analogy, and indeed all classification of plants by the number of the parts in question. Nothing could be more unnatural than to separate

Mosses

Mosses for this reason from the other Cryptogamic vegetables, and therefore Jussieu can scarcely believe these parts to be Cotyledons; yet it is not possible to call them any thing else, and to suppose them a peculiar, and hitherto unheard-of, organ, would but increase the difficulty. Gærtner in the Introduction to his great work, *p.* 157, tells us he has seen many Cotyledons in several *Fuci* also, and that he suspects others of the more imperfect plants, hitherto referred to the *Monocotyledones*, may be similarly circumstanced. It seems that too much, by far, has been taken for granted in this department, though the parts under consideration form the great hinge upon which all natural systems turn. It is only by analogy that the great family, or natural order, of *Lichenes* has been judged Monocotyledonous, an analogy which the *Fuci*, if Gærtner be correct, render very doubtful. The germination of the *Fungi* is at least equally uncertain.

I mean not however by any means to invalidate the importance of the distinction between such plants as have two or more Cotyledons, and such as have only one or none, however inaccurate the terms commonly used to distinguish them may be. Much less am I inclined to throw any needless impediments in the way of those who labour at the arduous and important study of natural classification, or to detract from the well-earned fame of such men as Gærtner and Jussieu, on account of difficulties and imperfections unavoidable in so abstruse a study. No real friend to truth and knowledge ever foments invidious rivalships in philosophy. The field of science is now so vast, that its different cultivators find the advantage of dividing their tasks, and thus the students of physiology, of natural systems, and of artificial ones, may all powerfully assist each other. Truth is pursued by different paths, and nothing is more pleas-

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ing than to see the various observers of Nature in a Society like ours, mutually and harmoniously contributing, as we have all along done, to enrich the scientific hive. I would therefore conclude by recommending those who have leisure and opportunity for the purpose, to observe for themselves the germination of the principal families of plants, not only of such genera as are in dispute, but of all about which there can be any doubt, most of which will easily be indicated by a comparison of Gærtner's work with the remarks in the foregoing pages.

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